AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

THE FASTEST OODA LOOP:

THE IMPLICATIONS OF BIG DATA FOR AIR POWER

by

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A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

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Maxwell Air Force Base, Alabama

June 2016

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ABSTRACT

At the recent World Economic Forum held in Davos, Switzerland in January 2016 the overwhelming topic of discussion was the implications of the coming "Fourth Industrial Revolution". One of the pillars of this revolution is what has become known as Big Data. Big Data is one of the fastest growing sectors of business and its users comprise everyone from United Parcel Services (UPS) to the Central Intelligence Agency (CIA). Silicon Valley startups continue to rake in millions of government and private investment dollars in the hopes that Big Data will continue to expand both the financial and informational return it is already providing.

Edward Snowden's revelations of the National Security Agency (NSA) spy programs in 2013 gave the world its first real glimpse into the Big Data programs that were already in use by intelligence agencies, such as the NSA facial recognition database[1]. Big Data use has also grown within the military structure in areas such as ground force operations and cyber warfare. Where Big Data has yet to make major inroads is in the arena of Air Power. Three scenarios will be considered to show the potential impacts Big Data could have on air power. Integrated properly into Air Operations as a decision aid and analysis tool, Big Data could be a tremendous aid for every warfighter – from the tactical level to commanders faced with complex strategic decisions.

Introduction

Dude 01 is a flight of 2 F-15E's tasked with Strike Surveillance and Reconnaissance in a kill-box over northern Syria. 10 minutes into their mission they receive a Link-16 Data Link text message and are tasked to destroy a convoy of 4 ISIS vehicles carrying weapons and suicide bombers that have just left Raqqah. What Dude 01 is unaware of is that the data gathered to task them was collected from a variety of sensors that included autonomous linguistic analysis, cell phone and electronic signal interception, and air-to-ground mover tracking radar. This data was collected, analyzed, and processed with enough accuracy that it required minimal to no human or man-in-the loop vetting of the information through Command and Control (C2). Consider another scenario where lost sorties due to maintenance issues or malfunctions drop 50 percent across Air Force airframes because maintenance teams possess an almost innate ability to diagnose and pre-emptively treat aircraft maintenance issues. Aircraft routinely return Code 1 (i.e. no malfunctions or degraded equipment) and every flight period of the day there is at least one spare aircraft in case any of the line aircraft experience maintenance issues during ground ops. Sound impossible? These two simple but hypothetical examples are a sample of what potential lies in the promise of implementing Big Data analysis across multiple aspects of air operations. Big Data can provide leaps in efficiency that was previously thought impossible. This paper aims to show the implications of the ways Big Data is currently revolutionizing the tech and business industry through changes in efficiency, locating patterns, finding present and future threats and possibilities, and what those implications mean for the Air Force.

Previous Academic Study

Big Data analysis is such a new technology that its potential applications are still in the early stages of being understood. In 2011, the McKinsey Global Institute detailed the exponential growth both in data volume and computing power and how these two factors create the phenomenon of Big Data. The increase in data availability could have major implications on everything from medical care to national defense. The McKinsey Institute believes that Big Data's importance can only be realized once it was implemented in a particular industry, and all industries from business to government need to get ahead of competitors or risk being at a significant disadvantage as technology grows[2]. In 2013, Joshi Sanat built a case for Big Data as the go-to solution for a myriad of government or business issues[3]. While he considers both the velocity and volume of information, his recommended process of analyzing that information does not take into account the needs of data analysis in a wartime setting. Also in 2013, Stew Magnuson describes how the military began to realize the importance of Big Data for intelligence operations. He describes the potential for decisions to be made far away from actual events by analyzing everything from social media feeds to street cameras in order to make real-time proactive decisions, and the abilities this can provide commanders looking to stay ahead of a threat or actively changing situation[4].

The papers previously mentioned were written when Big Data benefits were really beginning to come into focus. Big Data's contributions to military and defense occurred concurrently in highly classified operations within the NSA and CIA, and the ideas for implementation into airpower use were still in their infancy. In 2015, John Stillion described a future air-to-air combat scenario against a peer-level adversary that would lean heavily on data-linked aircraft and their ability to transfer large amounts of information between each

other[5]. Having been fielded for decades data-linked aircraft are not a new idea, but those networks must evolve in a way that leverages current technological trends. This sharing of information is just the beginning of what Big Data has to offer future air operations. Lastly in 2015, Nicholas Cowan details the advantages Big Data could bring to Air Operations, but argues that the process is currently hampered due to the bottlenecks in the Air Tasking Order (ATO) building process and the handcuffing of the warfighter that results due to over dependence on centralized control[6]. The ability for a warfighter or commander to make higher fidelity decisions is one of the key elements Big Data has the potential to fix in the age of contingency operations against rapidly changing adversaries and asymmetric threats. This paper will describe potential advantages that Big Data can bring to the tactical and strategic decision makers in the combat air operations environment.

Why Big Data Should be Implemented into Airpower

The pace of technological advances is happening so fast that national security is increasingly difficult to maintain in the air, space, and cyber domains. The traditional American edge in technology is closing quickly because of the rapid advancement of Chinese and Russian cyber capabilities and stealth technology, along with China's rapidly growing offensive ballistic missile portfolio[7]. In addition, the current fight against terrorist threats has made the traditional "force-on-force" concept and rules of engagement increasingly complex and difficult for the warfighter. The combination of a rapidly changing enemy and the increasing inability for the warfighter to make timely decisions due to complex rules of engagement (ROE) directly conflict with how success will be achieved in future conflicts. The bottleneck preventing the warfighter from gaining access to critical data is the current information flow of compiling information

from ISR sources, manually analyzing them at a command and control (C2) level, and disseminating the information manually out to the warfighter via commands or tasks. The amount of data being created has far outpaced the ability to analyze using our traditional methods[8]. This bottleneck could be "opened up" through the use of Big Data analysis by minimizing or in some cases eliminating the requirement of "man-in-the-loop" analysis. The growth of Big Data analysis has become critically important in the intelligence, cyber, and ground force communities to make informed decisions in response to enemy activity and blue force posturing. The use of Big Data in airpower operations is equally essential and needs to be considered, and in order to be successful must be fielded in a way that is not held back by traditional acquisition methods[9]. The air domain changes extremely rapidly and across a large geographic area in a relatively short period of time relative to other aspects of warfare. Big Data can help users make more informed decisions about their follow-on actions; however some believe it can make micromanagement problems even worse due to the insight Big Data can provide to a commander[10]. The adoption of Big Data analysis in airpower operations and its use by the warfighter, autonomous aircraft yet to be fielded, and command level decision makers will allow the US to maintain a technological edge while enhancing and speeding up the decentralization of execution.

Research Framework And Methodology

This research project will use a scenario-planning approach to build a case for the importance of using Big Data analysis as a new tool to help the warfighter and combatant commanders make more informed and timely decisions. Due to the relative infancy of this technology, a definition and brief description of what constitutes Big Data analytics will be

necessary. Examples of how Big Data has improved or transformed the business and technology sectors will be provided, and then current users in the DoD will be evaluated to see how Big Data has changed or advanced their operations. Scenarios will be built on the intersection of two axes of uncertainty: the centralized vs. decentralized decision-making and execution Big Data can bring along one axis and the degree of information that is analyzed in bulk or specifically tailored to a target along the other axis.

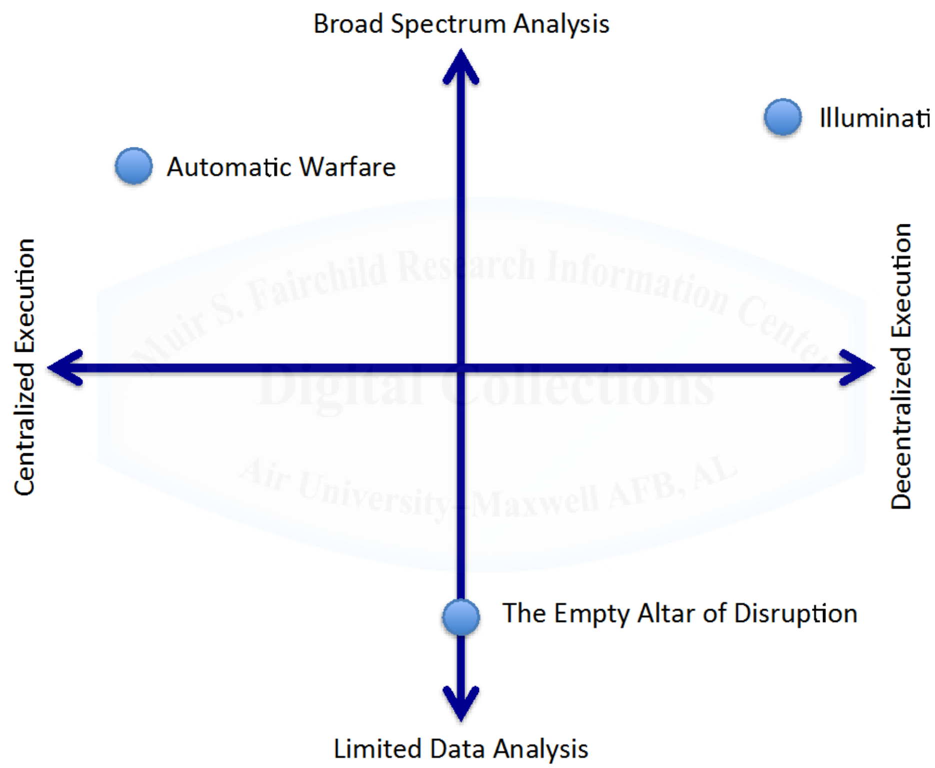

Figure 1: The Scenario Planning Matrix

Centralized decision-making is the execution and engagement authority occurring at a level above the warfighters doing the actual combat operations at the moment the combat is occurring. Decentralized decision-making is the execution and decisions made by those doing the fighting. These decisions occur within the confines of the Special Instructions (SPINS) and

Rules of Engagement (ROE) that have been previously established and also in situations the SPINS and ROE do not necessarily address. Broad Spectrum Analysis is when all information provided by Intelligence, Surveillance, and Reconnaissance (ISR), publicly available information, and documents are aggregated and available for Big Data to analyze for any relevant information. Limited Analysis is information collected and analyzed for a specific item, task, or target. The scenarios will attempt to paint a picture of the advantages and disadvantages of each aspect of implementation, and recommendations will be proposed based on the strengths of each scenario.

Why Big Data Will Be Important To Airpower

Big Data will be a significant force multiplier by providing everyone engaged in combat air operations – from maintenance and logistics to pilots, mission planners, and commanders a clearer picture of the Area of Responsibility (AOR) and mission needs, real and potential targets and target trends, and possible future threats. Big Data could help pilots quickly identify hostile or friendly forces on the ground or in the air, and supplement the clumsy Rules of Engagement (ROE) decision trees that aircrew do not have the time to reference or remember in a complex modern air combat scenario. Most importantly, Big Data compiled into a useful product can help to further decentralize execution by providing the warfighter and operational commanders all of the necessary information required to fight and win without having to wait for approval from higher command and control agencies.

Setting the Stage: What is Big Data?

Big Data is the technological progression of Data Analytics, and is a rapidly growing sector of the tech industry whose technology is now being used in fields from logistics to national security. While Data Analysis has existed since the early days of statistical analysis, it was not until recently that computing power reached a level where data sets of almost incomprehensible size could be analyzed to withdraw valuable information. More specifically, the International Data Corporation (IDC) defines Big Data technologies as ones "designed to economically extract value from very large volumes of a wide array of data, by enabling high-velocity capture, discovery, and/or analysis[11]." What this means is that Big Data is interested in all of the data points available in order to better draw out relevant analytical information about a subject. For example, some leading hedge funds such as Renaissance Technologies and MarketPsych lean on Big Data analysis not only track financial information, but also track social media, social media users geo-location, weather patterns, and global conflicts in order to develop an edge in trading strategies[12]. Initially it may not make sense that by pulling from seemingly uncorrelated information Big Data is able to provide greater insight into a situation or, as in the example above, develop a trading strategy. But in order for Big Data to work, a variety of sources is needed because Big Data depends on four Vs – volume, velocity, variety, and veracity of information[13].

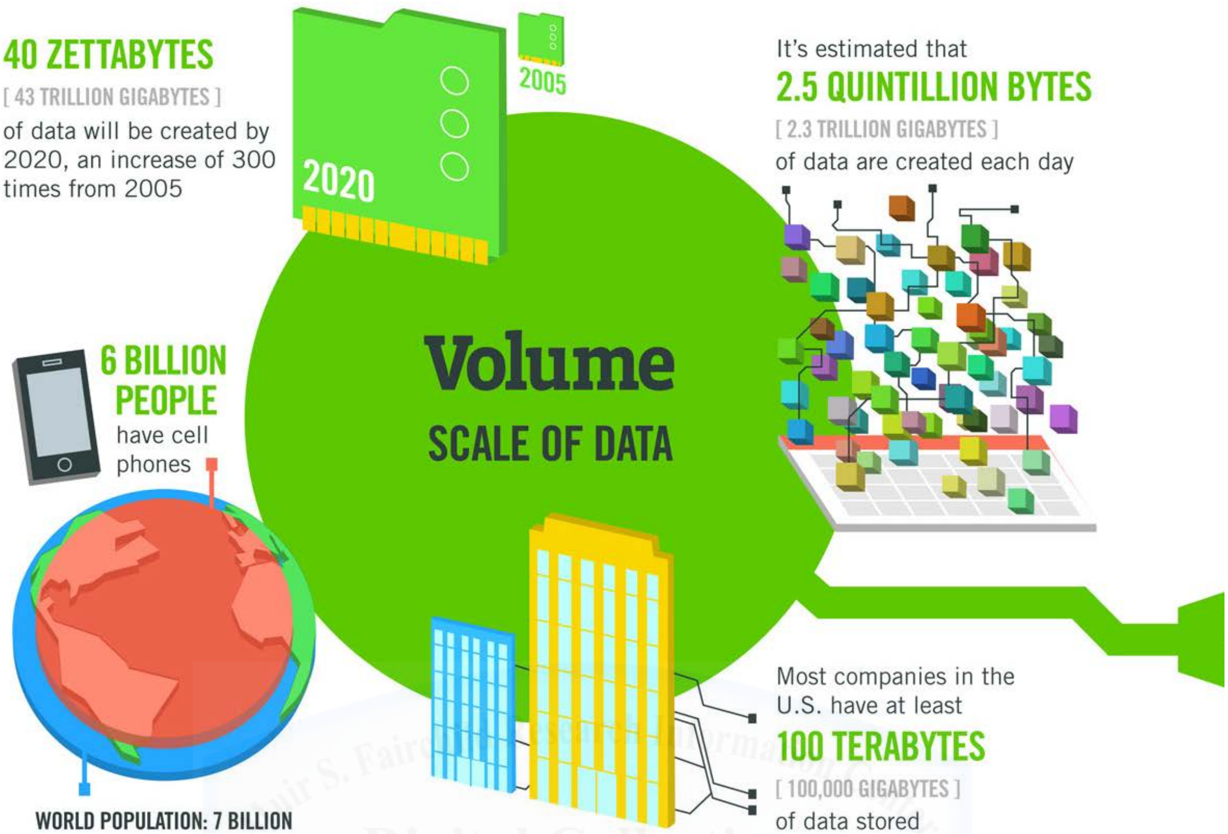

Figure 1: The first V of Big Data: *Volume.* (Reprinted from, *IBM Infographics & Animations: The Four V's of Big Data, 2013. http://www.ibmbigdatahub.com/infographic/four-vs-big-data)*

The *volume* of data consists of the amount of data that is being created in a given period of time. The exponential growth of the Internet means it takes less and less time for large amounts of data to be created. Larger data sets are better because more accurate information and projections can be obtained from large data sets, and Big Data is interested in enormous data sets even from traditional statistical points of view. For example, Google regularly examines datasets of many terabytes (a thousand gigabytes) and the sample size grows every second as new material is published online[14]. Data sets that can be considered "Big Data" are not specifically or formally defined but as a general rule the minimum to be considered is on the order of several

gigabytes (a gigabyte is one thousand megabytes, or one billion bytes) and the “minimum size” will grow as the amount of data also grows[15].

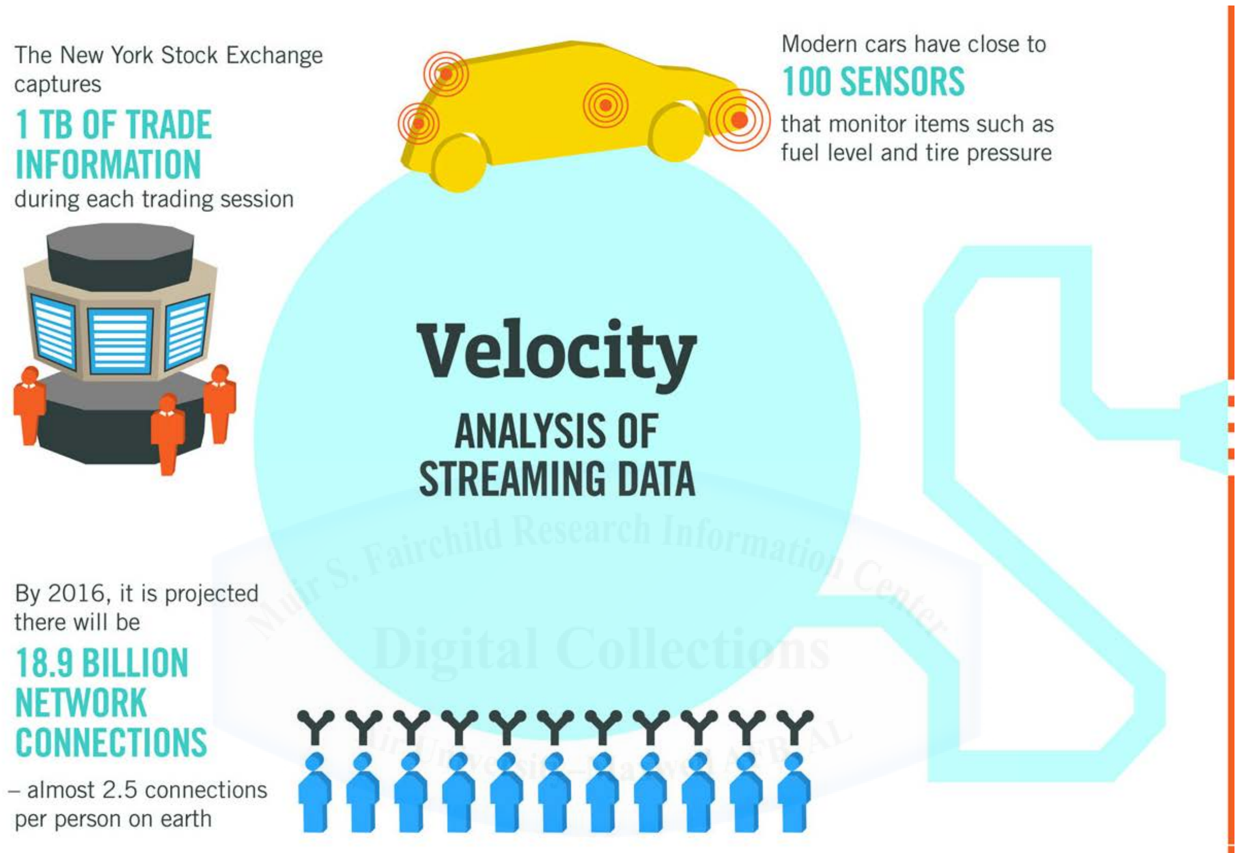

Figure 1: The second V of Big Data - *Velocity*. (Reprinted from, *IBM Infographics & Animations: The Four V’s of Big Data, 2013. http://www.ibmbigdatahub.com/infographic/four-vs-big-data)*

The *velocity* of data is a combination of two factors – how quickly the data is created and how quickly it can be analyzed. As the number of sensors grows the speed at which data is created grows at an exponential rate. For example, the explosion of “home sensors” and the “Internet of Things” such as your smartphone, Nest home thermostats, and Amazon Alexa, all

collect data about their environments and inputs to contribute to the growing body of data. The velocity of analysis is one of the cornerstones of distributed network "cloud" computing, and Big Data growth is a direct result of the increase in cloud computing capability[16].

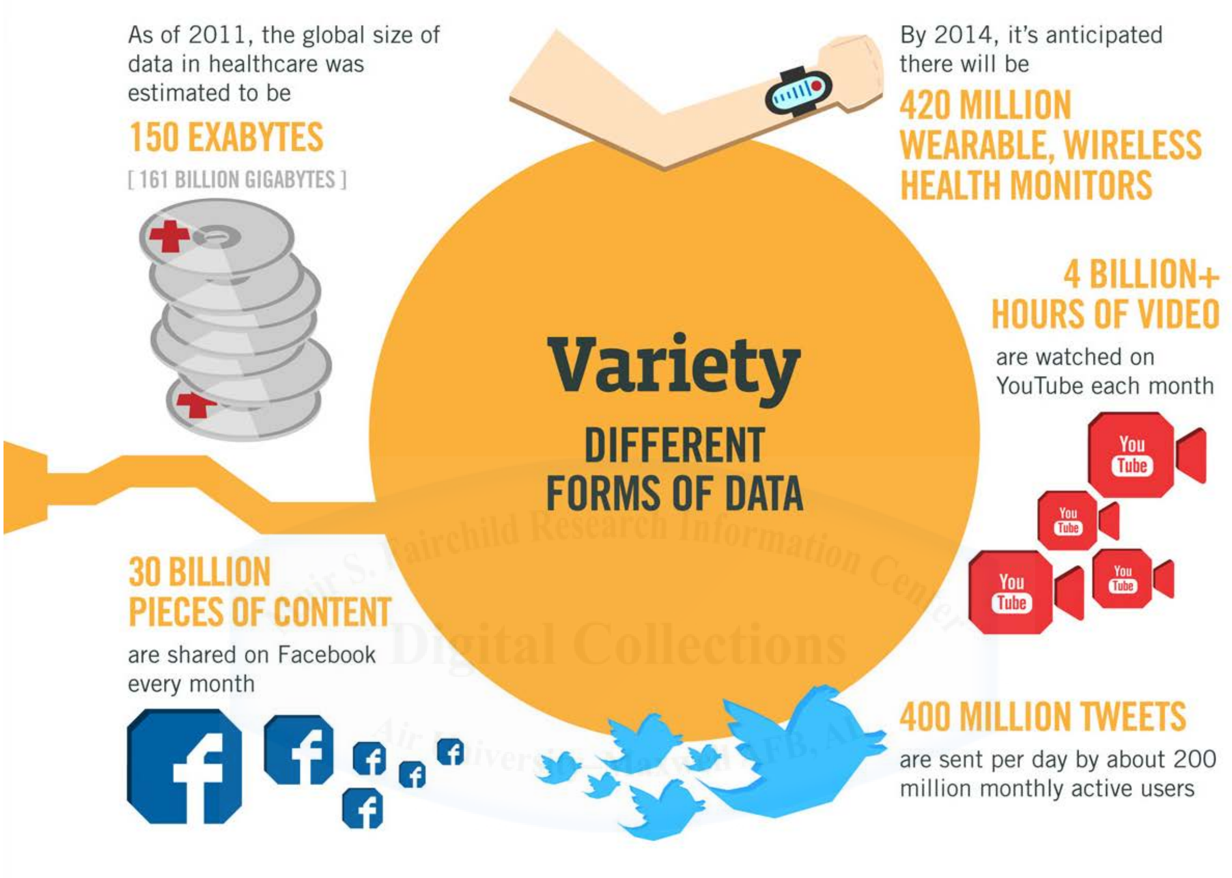

Figure 1: The third V of Big Data - *Variety*. (Reprinted from, *IBM Infographics & Animations: The Four V's of Big Data, 2013. http://www.ibmbigdatahub.com/infographic/four-vs-big-data)*

The growth in velocity ties into the third "V" of Big Data: *variety*. Unlike traditional statistics or other methods of data analysis that look at a specific point of information gathered from specific or similar items, Big Data is interested in all of the data available about everything and being able to profit or gain from that information, where *n*=all. For example, one of the Holy Grails of machine learning is the ability translate between languages autonomously,

eliminating the need for a human interpreter. Until the rise of Big Data, automated translation only had a "small" library of several million words to pull from and translate between, and the results were awkward at best, and at times completely incorrect. In 2006 Google devised the idea of using the Internet as its translation library – instantly increasing the library size from just over a billion words and sentences at the time to a library of several *trillions*. The result was Google Translate, which at the time was heralded as revolutionary and has only increased in accuracy and efficiency as the library of language information has grown[17].

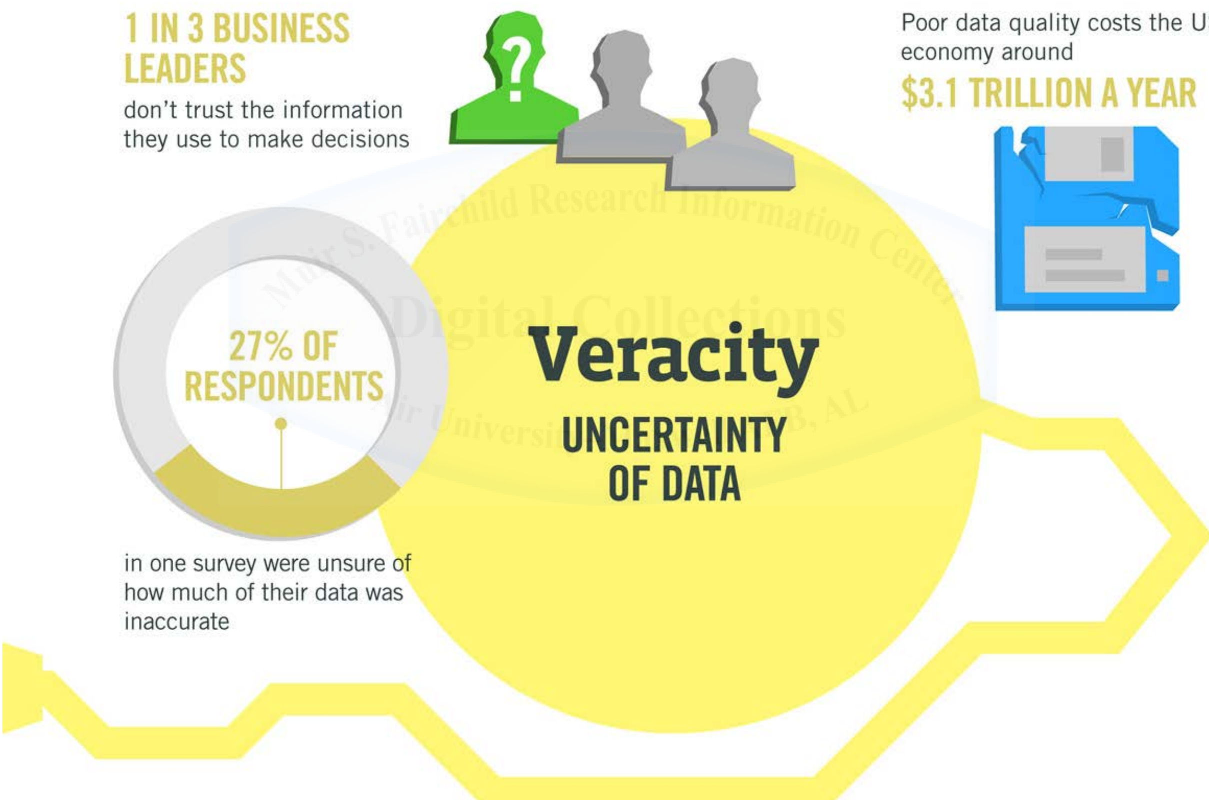

Figure 1: The final of the four V's of Big Data - *Veracity.* (Reprinted from, *IBM Infographics & Animations: The Four V's of Big Data, 2013, http://www.ibmbigdatahub.com/infographic/four-vs-big-data)*

The final V in Big Data is *veracity*, and while in some ways similar to the *variety* of information *veracity* is concerned with the messiness, disorganization, and overall accuracy of the information analyzed[18]. In simpler terms, in the way the definition of *veracity* deals with the accuracy or truthfulness of something, *veracity* in big data is concerned with ensuring the information being mined for use is accurate and most of all relevant. Various data sets such as video feeds, tweets, voice recordings, or photos can be analyzed, and the messiness consists of the collection of hashtags, typos, blurry and clear photos, abbreviations, and other elements that can affect the accuracy of analysis. In order to speed up Big Data analysis this information can be compressed, minimized, or filtered in order to achieve a more accurate result[19]. Because of the sheer amount of data available, how much of that messy information is relevant or can be used to create a relevant result is why *veracity* is one of the four pillars supporting the concept of Big Data.

"Big Data" as it is referred to today first emerged in 1999 when describing methods to analyze vast data sets that were rapidly growing as the Internet doubled in size every year[20]. The interest in Big Data exploded after 2010, with the number of academic papers on the topic of Big Data increasing significantly starting in 2008[21]. Companies such as Google and Amazon have since built their business models on the ability to analyze every available piece of data about their customers and users for business and profit. Much of the information gained by Intelligence, Surveillance, and Reconnaissance (ISR) aircraft is compiled for Big Data use by intelligence and defense agencies. The combination of data from electronic signals, visual recon, and satellite data is used today to find, fix, track, target, engage, and assess emerging threats, terrorist organizations, target patterns of life, and even predict where IEDs will be placed. The contribution of ISR and the explosive growth of drone operations since the onset of the War on

Terror has shortened the time required to locate, track, and engage potential targets compared to what was possible as recently as Desert Storm, but problems and delays still remain in the age of hybrid and non-state threats.

While the FBI/CIA/NSA/NRO and ground forces have actively used Big Data, Big Data has not been integrated in airpower operations in a way to take full advantage of its capabilities. One example of where Big Data could be useful is if the results of relevant analysis could be transferred between aircraft on an updated data-link into a simple visual display of mission relevant information. Another example would be in sortie analysis to better allocate resources for those times when the enemy is most active. Big Data will be a key piece in a next generation network that will absorb and analyze data from *all* potential sensors via cloud based computing, not just onboard or friendly aircraft connected to the current Fighter Data Link (FDL) network[22]. Positive Enemy Identification (PID) would be made easier due to the synthesis of information across ground, air, and space level surveillance, and this information could then be viewed by the warfighter in a usable format that is tailored for their mission[23]. Data provided by any capable ISR platform could analyzed in near real time, looking for patterns of life by High Value Individuals (HVI), mass enemy movement, the success or failure of target attacks, bomb hit assessment and desired weapons effects, target types, and target location to potential collateral damage and friendly forces.

Big Data could also improve airpower on the maintenance side. Data could be collected to find patterns and diagnostic information of parts that have been failing most recently or due to sortie types, which could improve the logistical flow of aircraft parts to meet the needs of maintainers before the breakages occur. A similar system is already in use with the F-35, but fourth generation aircraft could equally benefit in order to keep them flying longer. This could

greatly improve the fighting capabilities of squadrons in a wartime environment since there would be more airworthy aircraft available to send to the fight and have available for use as spares. The implementation of Big Data into all aspects of airpower is too important to be ignored, and with the rapid advancement and adoption of this technology the Air Force can maintain an edge against present and future adversaries.

Who Benefits from Big Data Now?

Many of the aspects of Big Data and the "what if" questions can leave some wondering if Big Data's advantages are limited to the tech industry or to secret organizations such as the NSA[24]. However, as Big Data is implemented into various industries it is becoming apparent that Big Data has something to offer nearly everyone.

The two most commonly known users of Big Data are Google and Facebook. Google's ability to allow a user to find almost any piece of information, map the entire world, and translate between languages automatically is all the result of Big Data analytics. Google's processing of data into a useful product is a direct result of its understanding that information can have multiple uses[25]. Google's aim is in the "datafication" of all of the information it can gain access too[26]. Google has used that data to create all of the tools we now use on a daily basis: the traffic updates on Google Maps; or the business hours of the restaurant you were planning on taking your significant other to on Friday night. Google pulls the restaurant hours from the restaurant website, and also can show you when hours are busiest based on web searches, online reservations, and restaurant website visits. How Google quantifies the data it has access to consists of complex coding languages such as MapReduce that can pull relevant pieces of information without having to organize the information first in a traditional sense[27]. This is why

Google is able to provide an answer to a search engine query in almost real time while the query is being typed. For example, the search term “big data and airpower” on Google returns approximately 73, 600 results in 0.66 seconds. By Google standards this is a low number of search results. In addition, Google initially returned *zero* hits on the phrase “big data and airpower” but automatically ran two separate searches for pages and documents that possess the term “big data” and “airpower” within the same item. Searching the term “big data” alone returns over 164 *million* – in 0.55 seconds. This example provides a small glimpse into the *velocity* of data and how Big Data can provide relevant and accurate predictions in a very short period of time, and can automatically re-route relevant information to an analyst in case the initial research pathway comes up short.

Facebook is known for its rabid appetite for user’s personal information. Facebook users post over 10 million photos per hour and click the “Like” button or comment on someone’s page over 3 billion times per day[28]. This information is then mined by Facebook’s programming language to learn about individual user’s preferences, interests, connections, and personal attributes[29]. In addition to the “public face” of social media that Facebook is known for, Facebook routinely cooperates with intelligence agencies such as the CIA and NSA. Facebook is considered a very reliable source of information regarding active terrorist networks and members and it often identifies indicators for potential terrorists and terrorist attacks.

While Facebook and Google are well known for their uses of Big Data, some of the “smaller” or rather lesser known users of Big Data are just as important. Former New York City mayor Michael Bloomberg gained his fortune by being a data pioneer who provides data streaming and analysis capability to major banks[30]. Another example is nearly any modern car manufacturer. Most modern cars possess over 40 processers, and many cars now also have

network connectivity of some kind (i.e. Wi-Fi or Bluetooth)[31]. This connectivity allows cars to send millions of data points back to the manufacturer for analysis, and in some cases the car can upload software fixes to adjust elements of the car's performance in order to improve the longevity of the parts without the user ever being aware the changes were made[32]. A final example is in the area of Human Resources. On the surface it is difficult to imagine how Big Data could be used in the Human Resource field, but the implications of its advantages can be frightening in scope. Behavioral analysis tools like Evolv track half a billion pieces of information across 18 industries. Data points covering everything from how much someone uses social media, their commute is to work, how they speak to their peers and managers, to using smart badges to track employee movements and which other employees they interact during a workday with helps Evolv determine which candidates and employees are the best workers[33]. Evolv clients such as Bank of America have been very impressed with the results and report an improved employee performance metric of 23% since adopting the Evolv program[34]. It is behavioral analysis tools such as Evolv and the ability of Big Data to provide measureable results to subjective elements such as Human Resources that have business, militaries, and countries scrambling to get ahead in the field of Big Data. While all of these examples come from the civilian sector, it only takes a little imagination to envision how Big Data's ability to process large amounts of information could be helpful in the arena of airpower, especially in the age of round the clock ISR.

Military and Defense Use of Big Data Thus Far

With the business impact of Big Data continuing to grow, the Department of Defense and other government agencies have taken notice and found uses for Big Data. One organization

that uses Big Data for national defense is the Department of Homeland Security (DHS). DHS is currently testing a program called Fast Attribute Screening Technology (FAST) to look for patterns in a person's behavior that point to potential future terrorist or criminal activity[35]. The FAST system tracks hundreds of different data points from observational, psychological, and biometric data through a variety of sensors at a customs checkpoint or important transit location, and then compares them against behaviors and activity traditionally seen by terrorists and criminals. The initial tests for the FAST system showed a greater than 70% success rate in identifying individuals with mal-intent or deceptive intent[36]. Individuals who were deemed potential threats by the FAST system could be subject to further screening or be arrested if illegal actions were discovered. While someone being screened cannot be arrested based on his or her perceived intent or ability to commit a crime, the FAST system has the potential to be a powerful deterrent to criminals and terrorists planning to enter the country.

Another area of national defense that relies heavily on the capabilities of Big Data is intelligence. Agencies such as the Central Intelligence Agency (CIA) and National Security Agency (NSA) rely on data analytics to process hostile actors' communications and perform targeted surveillance of person or organization[37]. These same intelligence agencies regularly work with commercial companies such as Google, Facebook, and Apple to find terrorists and locate their connections. In some cases intelligence agencies have outsourced their Big Data analysis to private companies to supplement and improve capabilities. CIA venture investments into secretive companies such as Palantir have paid off in software that tracks terrorist network connections. Palantir has most famously gained notoriety for helping the CIA find and kill Osama bin Laden by creating pattern algorithms that helped link the connections and people bin

Laden used throughout the Middle East to stay hidden[38]. Since that time the use of Big Data by intelligence agencies to stay one step ahead of the enemy has grown significantly.

A final example of Big Data's use in military operations has been by ground forces in the use of IED Placement, Blue Force Tracking, and locating times and areas of enemy activity. In Iraq, data analytics helped find the most common locations and repetitive patterns of IED placement and calculated the proposed "safest path" during a given day based on the collective analysis of IED strikes in a given area[39]. However, the military initially lacked the computing abilities to quickly analyze the data due to processing it on its standalone PCs. Adding to the computing problems of tracking IEDs was keeping track of friendly forces via blue force tracking data that provides near real-time information regarding the locations of friendly forces in a given area. The advantages of Big Data were provided once the processing was dislocated to the cloud and distributed via Big Data programming software across various military servers compared to individual PCs[40]. The cloud based processing times dramatically decreased and the capability to analyze information was also magnified. Instead of commanders only being able process blue force tracking for a specific area, they now track blue forces in the entire theater of operations and focus on a specific area when necessary[41]. Not only did patterns of IED placement start to emerge but so did patterns of blue force behavior that the enemy was exploiting[42]. In addition the enemy was attacking incident response teams due to their predictable fastest response routes. The new ability to observe patterns of activity allowed commanders to forecast when and where attacks most likely take place, where patrols should go and avoid, and how incident response teams can provide operational security while minimizing their own risk of attack en route[43]. This data spread between commanders and to officers leading patrols to speed up the decision cycle when friendly forces encounter enemy contact.

This example of how Big Data can supplement and speed up decision-making is especially important in military decision-making circles that execute the famous "OODA loop cycle" developed by the late Col John Boyd[44].

The Big Data Boost to the OODA Loop

Big Data can be a tremendous enhancement to the Observe, Orient, Decide, and Act (OODA) loop cycle that certain military branches, tactics, and strategies reference. The OODA loop cycle is dependent on four phases: Observe, Orient, Decide, and Act. The Observe phase involves the collection of information from various sources such as outside information, circumstances, or current interactions[45]. From those observations the information is Oriented and analyzed based on the decision makers background, new information, or previous experience[46]. Once the observations are oriented by analysis and synthesis into usable information, a Decision can be made on how best to proceed, and that decision drives the Action[47]. While there is a significant human element in the OODA loop (especially in the Orient phase), Big Data excels in being able to observe far more than even the most sophisticated and talented human observers could do on their own or in a team[48]. Big Data's additional strength in executing an OODA loop strategy is the ability to Orient data in a way to be visible to someone who may not otherwise be able to recognize it due to their own personal biases or background[49]. Big Data's "use" of the OODA loop consists of collecting data (Observe) and analyzing it to locate trends or specific points of interest (Orient). These first two steps are the most important parts of the OODA loop, and the proper use of the orient phase by collecting relevant data is critical to make successful decisions[50].   Big Data allows the orientation of data in such a way that decision makers can tailor the "operational picture" provided by the data to meet their needs

based on the task at hand[51]. Decision makers then have the ability to make more informed tactical and strategic decisions based on the data (Decide) to create a best course of action (Act). The cycle then repeats as the operational space changes in response to the action. Big Data's ability to provide fast and actionable information has tremendous implications for airpower operations. Proper execution of Big Data analysis into airborne warfare will provide commanders and warfighters the availability of the shortest possible OODA loop cycle in what is already one of the fastest and most fluid theaters of warfare.

So Why is Big Data Important to Air Power?

Even without a full understanding of the Big Data process a picture begins to emerge regarding how Big Data can help contribute to airpower operations. First and foremost, Big Data is not a solution that can with 100% accuracy predict the probability of a future event. However, Big Data's strength lies in the ability to synthesize extremely large amounts to data into smaller, more "digestible" and actionable pieces of information. For example, if one were to walk onto the operation floor of a Combined Air Operations Center (CAOC) for the first time it is easy to be immediately overwhelmed by the tremendous amounts of information flowing in through various sources. These sources can include civilian news sites, Remotely Piloted Aircraft (RPA) video feeds, Fighter Data Link (FDL) tracking map displays, Blue Force ground tracking screens, satellite video and data feeds, and any number of other dizzying sources all projected onto large stadium screens while surrounding an ocean of personal computer screens from the dozens of workstations occupying the CAOC floor. It is an overwhelming environment for even the most seasoned commander or multi-tasker. This is the very environment where Big Data analytics is most at home and where its capabilities can provide someone working in this

environment a greater ability to process and act on relevant information quickly – and execute the fastest OODA loop possible in an active situation.

Scenario Lead In

The examples mentioned above are a sampling of the many success stories detailing how Big Data is currently transforming business, technology, and defense. As the Air Force and DoD try to find ways to implement cutting edge technologies, there needs to be significant consideration of how Big Data should be integrated into current and future operations. The Air Force 2030 Air Superiority Flight Plan mentions Big Data capabilities such as cloud-based computing and combining data from the air, space, and cyberspace domains as essential to provide the United States an asymmetric advantage in a future conflict[52]. The importance of ISR contributions and the need to allocate sensors to the correct locations at the right time is another area where Big Data capabilities can shine by improving efficiencies in ISR collection[53]. This recognition of how Big Data will play a role in the Air Force's contribution in future conflicts is significant, but the current rate of technological change does not allow the Air Force to wait until 2030 before allowing Big Data to have a significant role. Other countries are already jumping headfirst into the Big Data ocean. The United Kingdom Ministry of Defense is pursuing the integration of Big Data into air operations and throughout its military[54]. On the potential adversary side China's seemingly unquenchable thirst for data and information about nearly everything is making them a power player in the Big Data arena. China is aggressively pursuing the tools of Big Data in order to keep a better tab on its citizens and encourage what it believes is better decision making[55]. If the US military and the Air Force wants to stay ahead in the midst

of the fourth industrial revolution, then it must take the advantages of Big Data seriously and begin aggressively pursuing how to integrate it into current operations.

Scenario Presentation

In April of 2025 tensions between the United States and Iran peak due to Iran's repeated blockades of the Hormuz Straight and sabre rattling against friendly and neutral nations within the Arabian Gulf, such as Oman and the United Arab Emirates (UAE). Intense internal strife within Iran from population desiring western-style freedoms and a representative democracy only goad the current government to display regular and disruptive signs of strength to the international community and neighboring countries. A critical tipping point is reached in August when Iran torpedoes an American patrol boat in international waters and shoots down a pair Qatari F-16's on a training mission outside of Iranian airspace. Efforts by the international community to calm the situation diplomatically are dashed a week later when Iran follows up these actions with an full blockade of the Hormuz Straight until it determines other nations "stop all hostile actions and cease all sanctions" and proceeds to sink civilian oil tankers that attempt to run the blockade. This causes massive monetary and environmental damage to the Arabian Gulf and an outcry by US allies in the Gulf region and around the world. Iran doubles down these actions by deploying fighter aircraft recently purchased from Russia onto its southern coast along with S-300 and S-400 surface to air missile systems and aggressive cyber attacks against US government, military, and financial institutions. The President authorizes the military to execute Combined Defense of the Arabian Gulf (CDAG) along with a coalition of friendly Middle Eastern nations such as UAE, Qatar, Saudi Arabia, Egypt, Jordan, and Kuwait. With that order the CAOC at Al Udeid airbase in Qatar goes in to full wartime footing and all US aircraft at

military bases and on carriers throughout the Gulf region are readied to execute strikes against Iran and defend the Arabian Gulf states.

In this future scenario, the CAOC and warfighters have access to Big Data capabilities in the form of a cloud-based program called the Enhanced Data Evaluation Network (EDEN). The degree to which this network is integrated in the decision-making OODA loop process is one of the key features the scenarios will be evaluated against. The extreme ends of integration vary from a full analysis of all pieces of data that are fed into the CAOC, from civilian news site to the most classified national assets, to the low end only using EDEN as a target analysis tool and threat detector. The second axis each scenario will contrast the degree to which EDEN is distributed to warfighters and allowed to influence decentralized execution. The extremes will vary between using the data EDEN provides at an exclusive central level and making warfighters increasingly dependent on Command and Control (C2) to integrating it fully into aircraft and data link networks to allow extremely decentralized decision making and execution. The scenarios assume that the US is engaged in active combat operations against Iran entailing aerial bombing, air-to-air engagement, naval combat, and cyber warfare. From this scenario, three different outcomes will be considered to help envision the ways Big Data could help a future fight such as this one.

Scenario 1: *Automatic Warfare*

In this scenario, Big Data combined with advancements in Artificial Intelligence (AI) have eliminated all but the most important decisions to be made by a commander. Mission sets such as traditional close air support (CAS) and strike coordination and reconnaissance (SCAR) have been replaced with tailored tasks created by algorithms. Drones of both the remotely

piloted and autonomous variety dominate the air and sea, and they have the capability to fire at and identify potential targets through the combined capabilities of AI and Big Data. Within the CAOC, commanders watch combat unfold in real time through the synthesis of various sensors and can task manned strike and air-to-air aircraft through a simple "point-and-click" interface that is connected directly to the Fighter Data Link (FDL). Airmen, joint forces, and allied nations execute a tasking with brisk efficiency, awaiting follow on orders in an almost robotic fashion. Every detail of their tasking, from time-on-target, to which type of ordinance to use and the final attack heading necessary to de-conflict from other aircraft are provided to operators. When Airmen locate potential targets they can clearly identify as hostile, that information is uploaded and processed by EDEN, where it is then distributed to commanders who can give the tasking to strike or continue gathering more information. Tasks can be delegated from the main air commander to area or lane commanders within the CAOC, who have replaced the traditional airborne mission commander (MC).

Analysis

In some circles of leadership, this combination of broad spectrum Big Data analysis and high levels of central execution could be the pinnacle of technological enhancements to war fighting outside of fully autonomous warfare. The high levels of central execution would be an evolution of the trends currently taking place in Operation Inherent Resolve (OIR). The idea of big data processing capability applied to ISR and advanced AI is key to the concept of the Common Operating Picture (COP) currently in design for future use[56]. This system would provide commanders with relevant, accurate, and correct information about the battle-space in real time and allow them to provide the best and most accurate instructions to those on the ground and in the air. The amount of situational awareness available to commanders and those

working in C2 would be unprecedented with COP system integrated into an EDEN-like tool. When warfighters find potential targets, wait times for analysis and approval to strike by C2 could be minimized if EDEN was allowed the flexibility to analyze all information coming into the battle space. This would provide a very clear picture of the mission to those doing the fighting, and commanders would have almost total control over the decisions taking place on the battlefield. Potential downsides of this type of Big Data integration would be the need for an expanded and robust C2 support staff needed to delegate the many tasks that would grow in this new Multi-Domain Command and Control (MD C2) environment[57]. This could potentially be a tall task in the current age of decreasing defense budgets and increasing problems with officer retention. There would have to be significant DoD investment into the EDEN system to ensure the visual analysis product would be useful and not detract from decision makers situational awareness, and those dollars could potentially be taken away from other weapons systems or manpower. Potential adversaries could limit information flowing to such a system through advanced jamming that could adversely affect the veracity – or accuracy – of information flowing toward the COP. The lack of accurate information flowing to those making such decisions could prove fatal to the effectiveness of a force that depends heavily on autonomous drones and centrally located decision makers without some sort of pre-emptive measure in place to delegate strike authority to those executing the mission.

The OODA loop impact of implementing EDEN in a high central control and broad data analysis environment would be a major boost to those working in the C2 environment. Commanders, analysts, liaison officers and decision makers would have a tremendous advantage by having the smallest possible decision making cycle relative to Iran's actions. Warfighters on the battlefield and in the tactical space however could be left out of the bigger picture and

become overly dependent on C2 under such a system. This system would hinge on strong C2 manpower and in order to be successful would also need a strong EDEN system failure contingency plan in place to minimize mission impact in case of degradation by the enemy.

Scenario 2: *The Empty Altar of Disruption*

Big Data has further evolved its role as a target analysis tool. Traditional roles like CAS and SCAR are maintained, and every day keeps a traditional ATO cycle of revolving mission sets, potential targets, and threats as the enemy center of gravity shifts in response. Airborne mission commanders lead large formations of manned and unmanned aircraft to strike targets in Iran and protect civilian infrastructure in the Gulf. When a new target is identified, every aspect of the target is analytically scrutinized for patterns of life, potential impact to the enemy centers of gravity, structural makeup of the target, and the best opportunity to strike and achieve desired weapons effects (DWE). Various specialists then aggregate the results of this analysis and prioritize targets for approval. Commanders confer daily with their staff to discuss the results of analysis across ground, air, and sea domains in order to decide the next day's ATO priorities. The ability of Big Data and AI to help commanders shape the battle space and be a strategic/tactical decision aid was killed years ago at the flag level due to concerns that algorithms cannot match the subjective intelligence and strategic analysis capabilities of an experienced and well-educated officer. This cautious approach combined with the fear of potential fallout from executing a decision based on analysis that is incorrect was fatal to a full integration of the EDEN system into the COP. Meanwhile in the civilian sector, Big Data analytics combined with AI and the web of sensors making up the Internet of Things have

revolutionized nearly every aspect of life, resulting in changes to society rivaling that of the industrial revolution.

Analysis

This scenario more or less continues the current method of operations within the decision making cycle, with Big Data taking on a supplemental role to help confirm the validity of potential targets. Much of the analysis in the Air Operations Center is still done manually by way of analysts responsible for various data feeds who then manually provide information they believe is relevant to their commander to help build his situational awareness[58]. By using EDEN as a target analysis tool, individuals in targeting cells at the MD C2 could have an increased ability to achieve DWE on targets and also help to weaponeer targets that ISR locates. This could for example provide commanders and Joint Terminal Attack Controllers (JTACs) a correct and fast weapon solution for targets such as HVIs hideouts. In addition, traditional mission sets such as CAS and SCAR would continue, but with even greater scrutiny on target selection.

The downsides of this method of implementation would chiefly be the slippery slope to "analysis paralysis" in response to potential targets and the desire for perfect weapons solutions on a target and zero civilian casualties. While some may argue this is already occurring in the present, Big Data analysis may exacerbate the problem – especially if patterns of life can be predicted with precision and accuracy. This could further complicate the bottleneck of commanders conferring with their staff to manually select targets based on EDENs recommendations. While EDEN would be helpful in determining short notice targets, there would be a high possibility of strategic target strikes being delayed due to over constant analysis of which targets would most affect the enemy center of gravity. On the tactical side, warfighters could still have too much reliance on C2 approval for legitimate dynamic targets. An ROE

matrix for employment without C2 or EDEN coordination could be created, but would also contribute to the current fog of war and delayed kill chain problems that are currently hampering operations.

The OODA loop execution of target/HVI analysis has had limited success in the current anti-terrorism conflict and can be adjusted for short notice “ad-hoc” tasks that need to be taken care of within the standard ATO cycle[59]. However, the Observe and Orient portions of the OODA loop are still limited by the “human” ability to manually decide on the data and the majority of commanders’ time is spent trying to gain situational awareness versus developing best courses of action[60]. This short notice environment is where the benefits of implementing EDEN as a specific target analysis tool could be most advantageous. This would be critical because the manual decision cycle can be an obstacle to commanders getting inside of an adversary’s OODA loop, which can slow down opportunities to shape the operational space and puts them on a reactive footing[61]. It is also a cycle that can be a detriment to airborne mission commanders due to C2 commanders injecting delayed tactical decisions into the battle space based on soda-straw ISR information verses the “big picture” provided by all of the assets in theater an airborne mission commander can have has at his or her disposal via the FDL[62]. While Big Data would provide ample benefits in the field of target analysis or predicted enemy courses of action, the full range of benefits could be held back due to limitations on its use.

Scenario 3: *Illuminati*

Big Data analysis permeates nearly every aspect of decision making on and off the battlefield. EDEN provides analysis not only to MD C2, but also access is also provided to warfighters in the ground and in the air by a mix of satellite and airborne control nodes.

Operators are able to tailor information EDEN provides to mission specific items, and can also adjust the way information is displayed visually in order to maximize tactical effectiveness without being overwhelmed by the data. The information EDEN provides is also integrated into the airborne data link, and information is passed between aircraft in order for the airborne mission commander to maximize situational awareness on the ground and in the air. Within the C2 facility, commanders still provide input to warfighters regarding decisions but have taken a significant “step back” as warfighters get access to the same information C2 has. ISR feeds go directly into EDEN for real time analysis, and the results are updated in a constant stream that provides commanders with very high levels of situational awareness. Rules of Engagement allow for AI and autonomous drones to employ weapons based on the results of EDENs data feed, and the airborne mission commander can task the drones via the data link. The boost EDEN provides to the OODA loop decision cycle makes it very difficult for Iran to respond in any coordinated manner.

Analysis

The use of broad spectrum Big Data to allow maximum decentralized execution would require a very expensive investment in the EDEN infrastructure to create this sort of scenario. Software integration between all the different types of airborne and ground assets would be a significant undertaking, and the current rate of acquisitions and approval processes would have to be completely disrupted to allow the tools to be used in a timely manner. If the investment was made despite these potential roadblocks the changes to warfare would be significant. This type of broad spectrum analysis would provide the warfighter and commander a boost to situational awareness of both the micro and macro picture, and could boost the decentralization of execution while still keeping commanders abreast of the developments on the battlefield. In

order for this to work at the maximum capacity for the warfighter, EDENs analysis and results could not detract from the warfighters ability to fight by adding to distractions or worrying about referencing the localized big data feed. This would best be accomplished if EDEN is integrated into the equipment the warfighter used and trained with on a daily basis, such as the fighter data link or helmet mounted heads up display and not as an additional sensor or “app” within the software of the aircraft. This would form a type of User-Defined Operating Picture (UDOP) that would be tailored to the end user from the COP that EDEN helped to create at the MD C2 level. The UDOP and COP together would provide warfighters and commanders extreme agility in decision making speed and responsiveness[63].

The downsides of such a system would first be the previously mentioned cost to develop it. Limited defense budgets would cause selective integration or competition between assets for EDEN access, thus preventing the full benefits to every warfighter. Another downside could be the double edged sword of technological innovation taking form in the long-term degradation of critical thinking skills that have made the US military such a successful fighting force. Officers and warfighters could become overly reliant on EDEN capacities, and be reluctant to make decisions with degraded information or if EDEN was completely disabled. Warfighters would need to have contingency measures in place that allowed for decentralized execution without overly draconian punishments for decisions that do not necessarily have the best outcome. Without these measures in place, there could be an increase in risk averse culture where warfighters have become overly reliant on technology to make decisions and fearful of repercussions if they do not “get it right” when making a decision without the aid of EDEN.

The OODA loop impact of broad spectrum Big Data combined with decentralized execution could be significantly positive for the warfighter and commanders. In execution with

a fully functional an integrated EDEN system, the Observe and Orient portions of the loop would be minimized and updated faster than any human team could accomplish manually. Combined with autonomous drones and AI this system could in theory be the fastest possible OODA loop reacting to changes in the battle space within milliseconds. The main way for an enemy force to counter this would be to have an equivalent or superior EDEN like system, or through sheer force of numbers and firepower with no regard for collateral damage. As mentioned in the downsides of this type of integration, there would also have to be contingency actions in place that mitigated the loss of OODA loop speed if the EDEN system was degraded, countered, or lost. If commanders or warfighters lost access to EDEN analysis, effective contingency plans would allow them to continue making decisions using their traditional sensor fusion methods, and this backup ability could be boosted with future technology, such as limited self-contained AI embedded within aircraft software.

Recommendations

1. Invest and fund Big Data processing capability into the current ISR analysis process. Create a *usable* product for C2 analysts that allows rapid recall of data relating to a potential target.

2. Integrate Big Data analysis into current and future Fighter Data Link systems.

3. Ensure that the COP developed for use by commanders within a C2 decision-making environment allows for easy visual understanding of the data that is not overwhelming or dependent on technical knowledge

4. Develop a UDOP that pulls only mission relevant information from the COP and is fully integrated within the warfighter's system and is not separate reference tool or program.

5. Ensure commanders have the ability to rapidly re-task and prioritize mission assets based on the results of Big Data analysis

Conclusion

The Air Force Future Operating Concept firmly places Big Data into the architecture of MD C2, the COP and UDOP. Big Data analysis *will* play a role in future conflicts, and the degree to which it does depends on the ways it is implemented. Big Data is projected to play a greater role in the civilian sector and will continue to see rapid growth as the ability to generate what is now becoming known as the fifth V of Big Data – Value – makes the demand for Big Data explode. The Intelligence communities have already put Big Data to use in their sectors, and the Air Force can be at the leading edge of Big Data incorporation into modern warfare and air power. In doing so it only stands to increase its ability fly, fight, and win.

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